TECHNICAL NOTES

U.S. DEPARTMENT OF AGRICULTURE   WYOMING   SOIL CONSERVATION SERVICE

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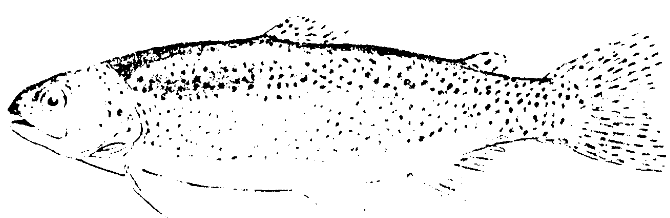
Subject: RAINBOW TROUT*

General

Because of variations in their life history pattern and the habitat in which they spend the majority of their adult lives, rainbow trout (Salmo gairdneri) can be subdivided into three basic ecological forms: (1) anadromous steelhead trout; (2) resident stream rainbow trout; and (3) lake or reservoir dwelling rainbow trout. It is important to recognize that there is a genetic or hereditary basis for each ecological form. For example, a "lake or reservoir" rainbow may react very differently to environmental stimuli associated with survival, feeding, and growth if it belongs to a population that has been evolving and adapting to the particular lake for hundreds or thousands of years when compared to hatchery rainbow trout that have just been released in the lake.

Nonanadromous rainbow trout are native to the Pacific Coast drainages inland as far as the Rockies and from the Rio del Presidio River in Mexico to the Kuskokwim River in Southwestern Alaska. They are also native to the Peace River drainage of British Columbia and the headwaters of the Athabaska River (of the McKenzie River basin) in Alberta. Their present range extends from the Arctic Circle to 550 south latitude. They are perhaps the most widely introduced fish species; the only continent lacking rainbow trout is Antarctica. Rainbow trout occur from 0 to 4,500 m above sea level.



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*Information taken from Ecoregion M3113 Handbook and Habitat Suitability Index Models, Wildlife Species Narratives (literature searches), U.S. Fish and Wildlife Service, various dates between 1978-1984.

Age, Growth, and Food

Female rainbow trout typically become sexually mature during their third year; males become sexually mature during their second or third year. Life expectancy averages 3 to 5 years in most southern lake populations, but life expectancy of steelhead and northern lake populations appears to be 4 to 8 years. Maximum size also varies with population, area, and habitat. Steelhead may grow to 122 cm long and weigh 16 kg. The average angler's catch is 3.6 to 4 kg. Great Lakes rainbow grow to 244 cm, but seldom exceed 9 kg. Size in wild rainbow trout appears to be a function of longevity, delayed age at maturity, and length *of* ocean residence for steelhead.

Adult and juvenile rainbow trout are basically opportunistic feeders and consume a wide variety of foods. Availability of different foods depends on many factors, including water type, season, and size of the trout. The diet of rainbow trout consists mainly of aquatic insects, although foods, such as zooplankton, terrestrial insects, and fish, are locally or seasonally important. The relative importance of aquatic and terrestrial insects to resident stream rainbow trout varies greatly among different environments, seasonally and daily, and with the age of the trout. Forty to fifty percent or more of the summer food of trout in headwater streams may be composed of terrestrial insects. Adult stream rainbow trout occasionally consume significant quantities of vegetation, mostly algae. Stream trout have no mechanism to break down cell walls in vegetation and cannot obtain nutrients from it, therefore, vegetation is thought to be consumed because of the invertebrates attached to it. Bottom fauna may comprise 83 to 94 percent of the winter diet of adult and juvenile lake rainbow trout. Lake trout usually reach 30 cm in length before they actively prey on other fish species.

Reproduction

Rainbow trout spawn almost exclusively in streams. Some rainbow and rainbow-cutthroat trout hybrids have successfully reproduced in lakes without tributary streams. Spawning in certain river systems may occur in intermittent tributary streams. In one case, up to 47 percent of the stream rainbow trout population spawned in intermittent tributaries that dried up in midsummer and fall. Spawning normally occurs from January to July, depending on location. Hatchery selection has resulted in fall spawning strains, and spawning of hatchery fish may occur in almost any month of the year, depending on the strain. A few populations outside of the native range have modified their spawning times to avoid adverse environmental conditions. Viable eggs have resulted from December and January spawning at water temperatures of 0.3° to 2.0°C in a tributary of Lake Huron. However, eggs exposed to long periods of 0° to 4°C temperatures suffered high mortality and abnormalities.

The female generally selects a redd site in gravel substrate at the head of a riffle or downstream edge of a pool. The redd pit, constructed primarily by the female, is typically longer than the female and deeper than her greatest body depth. Average depth of egg deposition is 15 cm.

Rainbow trout residing in lakes and reservoirs have a similar life history pattern to the steelhead trout, but generally lack a physiological smolt stage. Juveniles migrate from natal streams to a freshwater lake rearing area instead of to the ocean. Lake rainbow trout most commonly spend two summers in a stream and two summers in a lake before maturing. Spawning takes place during the growing season in an inlet or an outlet stream with more than 90 percent of the trout returning to the stream of natal origin. Lakes with no inlet or outlet streams generally do not possess a reproducing population of rainbow trout. Whether spawning adults enter through an inlet or an outlet, they and their progeny will return to the lake. These movements from natal site to lake rearing areas appear to be directed by genetic/environmental interactions.

Spawning usually begins one month earlier in the outlet than in the inlet; the difference in time is apparently related to temperature differences. In Bothwell Creek, a tributary of Lake Huron, 65 percent of the spawning run were repeat spawners. The typical survival rate of repeat spawners is 10 to 30 percent with extremes form 1 percent to more than 65 percent.

Average fecundity of rainbow trout is related to length, but is highly variable, ranging from 500 to 3,161 eggs per stream resident female. Fecundity of lake resident females ranges from 935 to 4,578 eggs per female with an average of 2,028 eggs per female.

Specific Habitat Requirements

Optimal rainbow trout riverine habitat is characterized by clear, cold water; a silt-free rocky substrate in riffle-run areas; an approximately 1:1 pool-to-riffle ratio, with areas of slow, deep water; well-vegetated streambanks; abundant instream cover; and relatively stable waterflow, temperature regimes, and streambanks.

Optimal lacustrine habitat is characterized by clear, cold, deep lakes that are typically oligotrophic, but may vary in size and chemical quality, particularly in reservoir habitats. Rainbow trout are primarily stream spawners and generally require tributary streams with gravel substrate in riffle areas for reproduction to occur.

Trout production is typically greatest in streams with a pool-to-riffle ratio of approximately 1:1. Pools are inhabited throughout the year by adult and juvenile stream rainbow trout. Pools are important to trout as a refuge from adverse conditions during the winter. Because pools differ in their ability to provide resting areas and cover, this model subdivides pools into three classes. One study found that streams with deep, low velocity pools containing extensive cover had the most stable trout populations.

Available trout literature does not often clearly distinguish between feeding stations, escape cover, and winter cover requirements. Prime requisites for optimal feeding stations appear to be low water velocity and access to a plentiful food supply; i.e., energy accretion at a low energy cost. Water depth is not clearly defined as a selection factor, and overhead cover is preferred, but not essential. Escape cover, however, must be nearby. The feeding stations of dominant adult trout include overhead cover when available. The feeding stations of subdominant adults and juveniles, however, do not always include overhead cover. Antagonistic behavior occurs at feeding stations and hierarchies are established, but escape cover is often shared.

Cover is recognized as one of the essential components of trout streams. One researcher was able to increase the number and weight of trout in stream sections by adding artificial brush cover and to decrease numbers and weight of trout by removing brush cover and undercut banks. One study reported that the amount of cover was important in determining the number of trout in sections of a Montana stream. Another study found that mean depth and underwater, overhanging bank cover were the most important variables in determining the density of brook and rainbow trout longer than 18 cm in a north-central Colorado stream. Cover for adult trout consists of areas of obscured stream bottom in water ≥ 15 cm deep with a velocity of ≤ 15 cm/sec. One study reported that, in larger streams, the abundance of trout ≥ 15 cm in length increased with water depth; most trout were at depths of at least 15 cm. Cover is provided by overhanging vegetation; submerged vegetation; undercut banks; instream objects, such as debris piles, logs, and large rocks; pool depth; and surface turbulence. A cover area of ≥ 25 percent of the total stream area provides adequate cover for adult trout; a cover area of ≥ 15 percent is adequate for juveniles. The main uses of summer cover are probably predator avoidance and resting.

In some streams, the major factor limiting salmonid densities may be the amount of adequate overwintering habitat rather than the amount of summer rearing habitat. Winter hiding behavior in salmonids is triggered by low temperatures. Cutthroat trout were found under boulders, log jams, upturned roots, and debris when temperatures neared 40 to 8°C, depending on the water velocity. One study found juvenile rainbow trout 15 to 30 cm deep in the substrate, which was often covered by 5 to 10 cm of anchor ice. Another study reported that, during winter, adult rainbow trout tended to move into deeper water (first class pools). One researcher indicated that downstream movement during or preceding winter did not occur if sufficient winter cover was available locally'. Trout move to winter cover to avoid physical damage from ice scouring and to conserve energy.

Headwater trout streams are relatively unproductive. Most energy inputs to the stream are in the form of allochthonous materials, such As terrestrial vegetation and terrestrial insects. Aquatic invertebrates are most abundant and diverse in riffle areas with rubble substrate and on submerged aquatic vegetation. However, optimal substrate for maintenance of a diverse invertebrate population consists of a mosaic of mud, gravel, rubble, and boulders, with rubble dominant. A pool-to-riffle ratio of about 1:1 (approximately a 40 to 60 percent pool area) appears to provide an optimal mix of food producing and rearing areas for trout. In riffle areas, the presence of fines (>10 percent) reduces the production of invertebrate fauna.

Canopy cover is important in maintaining shade for stream temperature control and in providing allochthonous materials to the stream. Too much shade, however, can restrict primary productivity in a stream. Stream temperatures can be increased or decreased by controlling the amount of shade. About 50 to 75 percent midday shade appears optimal for most small trout streams. Shading becomes less important as stream gradient and size increase. In addition, a well vegetated riparian area helps control watershed erosion. In most cases, a buffer strip about 30 m wide, 80 percent of which is either well vegetated or has stable rocky streambanks, provides adequate erosion control and maintains undercut streambanks characteristic of good trout habitat. The presence of fines in riffle-run areas can adversely affect embryo survival, food production, and cover for juveniles.

There is a definite relationship between the annual flow regime and the quality of trout habitat. The most critical period is typically during base flow (lowest flows of late summer to winter). A base flow >50 percent of the average annual daily flow is considered excellent for maintaining quality trout habitat, a base flow of 25 to 50 percent is considered fair, and a base flow of < 25 percent is considered poor.

<u>Adult.</u> Dissolved oxygen requirements vary with species, age, prior acclimation temperature, water velocity, activity level, and concentration of substances in the water. As temperature increases, the dissolved oxygen saturation level in the water decreases, while the dissolved oxygen requirement for fish increases. As a result, an increase in temperature resulting in a decrease in dissolved oxygen can be detrimental to the fish. Optimal oxygen levels for rainbow trout are not well documented, but appear to be ≥7 mg/l at temperatures ≤15°C and ≥9 mg/l at temperatures >15°C. Two researchers demonstrated that swimming speed and growth rates for salmonids declined with decreasing dissolved oxygen levels. In the summer (≥10°C), cutthroat trout generally avoid water with dissolved oxygen levels of less than 5 mg/l.

The incipient lethal level of dissolved oxygen for adult and juvenile rainbow trout is approximately 3 mg/l or less, depending on environmental conditions, especially temperature. Although fish can survive at concentrations just above this level, they must make various physiological adaptations to low levels of dissolved oxygen that may jeopardize their health. For example, low levels of dissolved oxygen can result in reduced fecundity and even prevent spawning. Large fluctuations in dissolved oxygen may cause a reduction in food consumption and impaired growth.

The upper and lower incipient lethal temperatures for adult rainbow are 25° and 0°C, respectively. Zero growth rate occurred at 23°C for rainbow trout in the laboratory. Changes in the natural growth rate of rainbow trout are detrimental to their development and survival. Therefore, 25°C should De considered the upper limit suitable for rainbow trout and then only for short periods of time. Adult lake rainbow trout select waters with temperatures between 7° to 18°C and avoid permanent residence where temperatures are above 18°C. Adult stream rainbow trout select temperatures between 12.0° and 19.3°C. Two researchers reported that the greatest scope of rainbow trout activity occurred at 15° and 20°C when tested at 5°C temperature intervals. Stream rainbow trout select temperatures between 12° and 19°C; lake resident trout avoid temperatures >18°C. Therefore, the optimal temperature range for rainbow trout is assumed to be 12° to 18°C.

The depth distribution of adult lake rainbow trout is usually a function of dissolved oxygen, temperature, and food. Adult lake rainbow trout remain at depths ≤ the 18°C isotherm and at dissolved oxygen levels> 3 mg/l.

Focal point velocities for adult cutthroat trout at territorial stations in Idaho streams were primarily between 10 and 14 cm/sec, with a maximum of 22 cm/sec. The focal point velocities for adult rainbow trout are assumed to be similar.

Precise pH tolerance and optimal ranges are not well documented for rainbow trout. Most trout populations can probably tolerate a pH range of 5.5 to 9.0 with an optimal range of 6.5 to 8.0.

One study suggested that the correlation between the winter steelhead run and increased water volume indicates that a freshet condition is required to initiate upstream movement of spawners. Another study stated that speed of migration of summer-run steelhead in the Rogue River was inversely related to temperature and directly related to streamflows. One researcher observed that steelhead migration into the Iron Gate fish hatchery ceased when the water temperature dropped to 4°C and did not resume for several weeks until the temperature increased. This suggests that water temperatures should be >4°C, but ≤18°C, and streamflow conditions should be above normal seasonal flows during upstream migrations of steelhead adults.

Embryo. Incubation time varies inversely with temperature. Eggs usually hatch within 28 to 40 days, but may take as long as 49 days. The optimal temperature for embryo incubation is about 70 to 12°C. One study reported increased mortalities of rainbow embryos at temperatures <7°C and normal development at temperatures ≥7° but ≤12°C. The optimal water velocity above rainbow trout redds is between 30 and 70 cm/sec. Velocities less than 10 cm/sec or greater than 90 cm/sec are unsuitable.

The combined effects of temperature, dissolved oxygen, water velocity, and gravel permeability are important for successful incubation. In a 30 percent sand and 70 percent gravel mixture, only 28 percent of implanted steelhead embryos hatched; of the 28 percent that hatched, only 74 percent emerged. Optimal spawning gravel conditions are assumed to include ≤5 percent fines; ≥30 percent fines are assumed to result in low survival of embryos and emerging yolk-sac fry. Suitable incubation substrate is gravel that is 0.3 to 10.0 cm in diameter. Optimal substrate size depends on the size of the spawners, but is assumed to average 1.5 to 6.0 cm in diameter for rainbows <50 cm long and 1.5 to 10.0 cm in diameter for spawners ≥50 cm long. One study reported that salmonids that incubated at low dissolved oxygen levels were weak and small with slower development and more abnormalities. Dissolved oxygen requirements for rainbow trout embryos are not well documented, hut are assumed to be similar to the requirements for adults.

Fry. Rainbow trout remain in the gravel for about 2 weeks after hatching and emerge 45 to 75 days after egg fertilization, depending on water temperature. When moving from natal gravels to rearing areas, rainbow trout fry exhibit what appears to he three distinct genetically controlled movement patterns: (1) movement downstream to a larger river, lake, or to the ocean; (2) movement upstream from an outlet river to a lake; or (3) local dispersion within a common spawning and rearing area to areas of low velocity and cover. Fry of lake resident fish may either move into the lake from natal streams during the first growing season or overwinter in the spawning stream and move into the lake during subsequent growing seasons.

Fry residing in streams prefer shallower water and slower velocities than do other life stages of stream trout. Fry utilize velocities less than 30 cm/sec, but velocities less than 8 cm/sec are preferred. Fry survival decreases with increased velocity after the optimal velocity has been reached. A pool area of 40 to 60 percent of the total stream area is assumed to provide optimal fry habitat. Cover in the form of aquatic vegetation, debris piles, and the interstices between rocks is critical. One study states that younger trout live in shallower water and stay closer to escape cover than do older trout. Few fry are found more than 1 m from cover. As the young trout grow, they move to deeper, faster water. One study suggested that one reason for this movement was the need for cover, which is provided by increased water depth, surface turbulence, and substrate that consists of large material.

Stream resident trout fry usually overwinter in shallow areas of low velocity near the stream margin with rubble being the principal cover. Optimal size of substrate used as winter cover by rainbow fry and small juveniles ranges from 10 to 40 cm in diameter. An area of substrate of this size class that is ≥10 percent of the total habitat probably provides adequate cover for rainbow fry and small juveniles. The use of small diameter rocks (gravel) for winter cover may result in increased mortality due to greater shifting of the substrate. The presence of fines (≥10 percent) in the riffle-run areas reduces the value of the area as cover for fry and small juveniles. One study reported a preferred temperature range of 13° to 19°C for fry. Because fry occupy habitats contiguous with adults, their temperature and oxygen requirements are assumed to be similar to those of adults.

Juvenile. One researcher reported focal point velocities for juvenile cutthroat in Idaho of between 10 and 12 cm/sec with a maximum velocity of 22 cm/sec. Metabolic rates are highest between 11° and 21°C with an apparent optimal temperature between 15° and 20°C. In steelhead streams, temperatures should be <13 but >4°C (optimal 7° to 10°C) from March until June for normal smoltification to occur.

Common types of cover for juvenile trout are upturned roots, logs, debris piles, overhanging banks, riffles, and small boulders. Young salmonids occupy different habitats in winter than in summer with log jams and rubble important as winter cover. One researcher observed that larger cutthroat trout (>15 cm long) and juveniles (≤15 cm) tended to use instream substrate cover more often than they used streamside cover (undercut banks and overhanging vegetation). However, juvenile brown trout preferred streamside cover. An area of cover ≥15 percent of the total habitat area appears to provide adequate cover for juvenile trout.

Because juvenile rainbow trout occupy habitats contiguous with adults, their temperature and oxygen requirements are assumed to be similar.